VIII.8 Hydrogen Safety Panel and Hydrogen Safety Knowledge Tools

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Project Start Date: 2004
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

- Provide expertise and recommendations to DOE and help identify safety-related technical data gaps, best practices and lessons learned.
- Help DOE integrate safety planning into funded projects to ensure that all projects address and incorporate hydrogen and related safety practices.
- Collect information and share lessons learned from hydrogen incidents and near misses with a goal of preventing similar safety events from occurring in the future.
- Capture vast and growing knowledge base of hydrogen experience and make it publicly available to the "hydrogen community" and stakeholders.

Fiscal Year (FY) 2014 Objectives

- Conduct ongoing safety assessments of DOE projects through project reviews and site visits.
- Develop a Panel position on the safety of hydrogen systems installed in outdoor enclosures.
- Increase number of records in database by encouraging "incident owners" to share lessons learned with the hydrogen community.
- Enhance utility of the safety knowledge tools.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Safety, Codes and Standards section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

(A) Safety Data and Information: Limited Access and Availability

(C) Safety is Not Always Treated as a Continuous Process

(D) Lack of Hydrogen Knowledge by AHJs (Authorities Having Jurisdiction)

(G) Insufficient Technical Data to Revise Standards

Contribution to Achievement of DOE Safety, Codes and Standards Milestones

This project contributes to achievement of the following DOE tasks and milestones from the Hydrogen Safety, Codes and Standards section (3.7) of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

- Task 1: Address Safety of DOE R&D (research and development) Projects (ongoing)
- Task 5: Dissemination of Data, Safety Knowledge and Information (ongoing)
- Milestone 5.1: Update safety bibliography and incidents databases. (4Q, 2011–2020)

FY 2014 Accomplishments

- Conducted the 19th Hydrogen Safety Panel (HSP) meeting in Washington, D.C., December 10–12, 2013, and the 20th meeting at the National Renewable Energy Laboratory in Golden, CO, May 13–15, 2014.
- Participated in 13 project reviews (including safety plan and design review activities) since July 1, 2013 for projects in fuel cell and hydrogen storage R&D.

- Completed an HSP white paper, "Safety of Hydrogen Systems Installed in Outdoor Enclosures" [1].
- Authored an *NFPA Journal* (National Fire Protection Association) article focusing on hydrogen safety, which highlighted the HSP and DOE's Hydrogen Emergency Response Training for First Responders.
- Presented an educational session at the 2014 NFPA Conference & Expo, Las Vegas, NV, on June 10, 2014.
- Led a planning session in April 2014 of 20 organizations/stakeholders to consider what electronic safety would benefit the next phase of hydrogen and fuel cell commercialization.
- Added four new safety event records to "H2Incidents.org" since the 2013 Annual Merit Review and Peer Evaluation Meeting, for a total of 214 records currently in the database.
- Released a first-of-its-kind iPad/iPhone app to enhance the utility and integration of the safety knowledge tools (h2incidents.org and h2bestpractices.org) with other safety planning resources.

INTRODUCTION

Safety is essential for realizing the "hydrogen economy"—safe operation in all of its aspects from hydrogen production through storage, distribution and use; from research, development and demonstration to deployment and commercialization. As such, safety is given paramount importance in all facets of the research, development, demonstration and deployment work of the DOE Fuel Cell Technologies (FCT) Office. This annual report summarizes activities associated with two projects, the Hydrogen Safety Panel and Hydrogen Safety Knowledge Tools.

Recognizing the nature of the DOE FCT program and the importance of safety planning, the HSP was formed in December 2003 to bring a broad cross-section of expertise from the industrial, government and academic sectors to help ensure the success of the program as a whole. The experience of the Panel resides in industrial hydrogen production and supply, hydrogen R&D and applications, process safety and engineering, materials technology, risk analysis, accident investigation and fire protection. The Panel provides expertise and recommendations on safety-related issues and technical data gaps, reviews individual DOE-supported projects and their safety plans and explores ways to bring best practices and lessons learned to broadly benefit the FCT program. The Panel is currently composed of 15 members having over 400 years of industry and related experience (see Table 1 for FY 2014 Panel membership).

TABLE 1. Hydrogen Safety Panel

Nick Barilo, Project Manager	PNNL
Bill Fort, Chair	Shell Global Solutions (ret)
David Farese	Air Products and Chemicals
Larry Fluer	Fluer, Inc.
Don Frikken	Becht Engineering
Aaron Harris	Sandia National Laboratories
Richard Kallman	City of Santa Fe Springs, CA
Chris LaFleur*	Sandia National Laboratories
Miguel Maes	NASA White Sands Test Facility
Larry Moulthrop*	Proton OnSite
Glenn Scheffler	GWS Solutions of Tolland, LLC
Andrew Sherman	Powdermet Inc.
Ian Sutherland	General Motors
Steven Weiner	PNNL
Robert Zalosh	Firexplo

* New Panel members

The widespread availability and communication of safety-related information are crucial to ensure the safe operation of future hydrogen and fuel cell technology systems. The entire hydrogen community benefits if hydrogen safety-related knowledge is openly and broadly shared. To that end, PNNL continues to improve the safety knowledge software tools and develop new techniques for disseminating this information. This report covers the Hydrogen Lessons Learned database (http://h2tools.org/lessons/), the Hydrogen Safety Best Practices online manual (http://h2bestpractices.org), the Hydrogen Tools iPad and iPhone apps as well as efforts to identify the need for new electronic resources. These resources are key to reaching, educating and informing stakeholders whose contributions will help enable the deployment of new hydrogen and fuel cell technologies.

APPROACH

The HSP strives to raise safety consciousness most directly at the project level through organizational policies and procedures, safety culture and priority. Project safety plans are reviewed to encourage thorough and continuous attention to safety aspects of the specific work being conducted. Panel-conducted safety reviews focus on engagement, learning, knowledge-sharing and active discussion of safety practices and lessons learned, rather than as audits or regulatory exercises. Through this approach, DOE and the HSP are trying to achieve safe operation, handling and use of hydrogen and hydrogen systems for all DOE projects.

The Hydrogen Lessons Learned database (h2tools.org/lessons/) facilitates open sharing of lessons learned from

hydrogen safety events to help prevent similar events in the future. DOE-funded project teams and others are encouraged to voluntarily submit records of incidents and near-misses, along with specific lessons learned. The addition of new records is also pursued by actively seeking news reports on hydrogen events, searching existing databases and encouraging self-submittals by "incident owners."

Hydrogen Safety Best Practices (H2bestpractices.org) is an easy-to-use, Web-based manual focusing on the safe use of hydrogen. It has been compiled from learnings and observations from HSP site visits, safety plan reviews, and other work, and available reference materials tailored specifically to working with hydrogen. Links are provided to other Web-based resources and supporting information to enhance the usefulness of this resource. Experts from the HSP, national laboratories, and other subject matter experts contribute and review new material added to the site. PNNL staff members, with assistance from the HSP, respond to user questions and comments.

RESULTS

The 19th and 20th meetings of the Hydrogen Safety Panel were held in Washington, D.C., December 10–12, 2013, and Golden, CO, May 13–15, respectively. The meetings provided opportunities to consider timely and relevant safety issues and provide direct input to the FCT Office. Details of the topics discussed and outcomes of the meetings can be found in the meeting minutes [2,3]. Two Panel task groups were formed at the 19th meeting to 1) perform a risk assessment of hydrogen equipment enclosures and 2) evaluate the current NREL Secure Data Center composite data products and templates to allow the Panel to better utilize the actual safety-related data and information reported by project teams in support of safety learnings. A Panel task group was formed during the 20th meeting to review the document, "Safety Planning Guidance for Hydrogen and Fuel Cell Projects," dated April 2010, and propose improvements based on the Panel's recent experiences with demonstration projects and early engagement activities.

A white paper report, "Safety of Hydrogen Systems Installed in Outdoor Enclosures," was issued in November 2013 [1]. The paper resulted from observations and considerations stemming from the Panel's work on early market applications. The paper focused on hydrogen system components that are installed in outdoor enclosures and proposed that a technical basis be developed to enable code bodies to write requirements for the range of enclosures from the smallest to the largest. A Panel task group was formed to follow up the white paper with a risk assessment on enclosures. Results from the task group's activities in April/May 2014 supported public comments submitted to the NFPA 2, "Hydrogen Technologies Code" technical committee in support of changes for the 2016 edition of the code.

During the past year the Panel has provided various safety review and support to projects as noted in Table 2. Since 2004, the Panel has participated in 399 project reviews (including safety plans, site visits reviewed, follow-up interviews and design review activities). Three of these projects utilized the early project involvement approach discussed in the FY 2013 annual progress report [4]. The results of those reviews were impactful by identifying significant project issues early enough to allow consideration by project teams.

Sharing and disseminating safety information and knowledge continues to be an important aspect of HSP work. For example, PNNL authored an *NFPA Journal* article focusing on hydrogen safety, which highlights the Panel and DOE's Hydrogen Emergency Response Training for First Responders [18]. The *NFPA Journal* is the official magazine of the National Fire Protection Association and reaches all

TABLE 2. HSP Project Safety Work since July 1, 2013

Work	Project Title	Contractor
Safety plan review [5]	Cryogenic Pressure Vessel Refueling	Lawrence Livermore National Laboratory (LLNL)
Safety plan reviews [6,7]	Fuel Cell Auxiliary Power Unit for Refrigerated Trucks	Nuvera
Project design review [8]	Energy Systems Integration Facility Fueling Station	National Renewable Energy Laboratory
Project design review [9]	Lawrence Livermore National Laboratory Cryogenic Refueling and Testing Facility	Lawrence Livermore National Laboratory
Safety plan reviews [10,11]	Demonstration of a Fuel Cell-powered Transport Refrigeration Unit	Plug Power
Safety plan reviews [12]	Fuel Cell Powered Airport Ground Support Equipment Deployment	Plug Power
Safety plan review [13]	Marine Corps Base Hawaii Hydrogen Fueling Station	Hawaii Natural Energy Institute
Safety plan reviews [14]	High Performance, Durable, Low Cost Membrane Electrode Assemblies for Transportation Applications	3M
Safety plan review [15]	New Fuel Cell Membranes with Improved Durability and Performance	3M
Project design review [16]	Maritime Fuel Cell Generator Project	Sandia National Laboratories
Safety plan review [17]	Fuel Cell Hybrid Electric Drayage Truck Demonstration Project	Vision Motor Corp

association members (70,000 individuals in 100 countries). PNNL also presented the educational session, "Design to Operation: Integrating Safety into Hydrogen and Fuel Cell Projects," at the 2014 NFPA Conference & Expo, Las Vegas, NV, on June 10, 2014 [19]. The session focused on activities for integrating safety into a hydrogen project and the resources available to designers, AHJs and first responders.

International collaboration is important to PNNL's hydrogen safety work. PNNL participated in a European/U.S. bilateral webinar, "What Can We Learn from Hydrogen Safety Event Databases?," held during the 5th International Conference on Hydrogen Safety in Brussels, Belgium on September 10, 2013 [20]. The webinar brought lessons learned and related knowledge to the forefront of the hydrogen community. PNNL also offered highlights of accomplishments of the HSP and other international collaborations through two presentations [21,22]:

- "Deploying Fuel Cell Systems: What Have We Learned?," which examines safety considerations in early market applications for hydrogen and fuel cell systems.
- "Advancing the Hydrogen Safety Knowledge Base," a white paper of the IEA Hydrogen Implementing Agreement Task 31 describing the value created and knowledge enhanced through member collaborations.

PNNL completed its work as leader for Task 31/Subtask D – Knowledge Analysis, Dissemination and Use and submitted the subtask final report [23].

During FY 2014 PNNL also focused on enhancing the HSP's role as a safety resource for enabling the widespread acceptance of hydrogen using branding (see Figure 1). Branding serves two primary functions:

- The consistent and appropriate use of branding will strengthen recognition of the Panel and its reputation as a safety resource
- Branding will validate that information is coming from a reliable and credible source

The branding is being implemented across the entire PNNL hydrogen safety project, including the HSP, Safety Knowledge Tools and First Responder Training.

The safety knowledge tools (Hydrogen Lessons Learned database and Hydrogen Safety Best Practices online manual) continue to see a steady number of users. To increase visibility and broaden the audience, the project has integrated information from the websites into a mobile application. The "Hydrogen Tools" app was released to the iPad and iPhone in September 2013 and adds value by combining information from the websites (h2tools.org/lessons/ and H2bestpractices.org) and other project resources (safety planning guidance and a safety checklist), calculators and related tools. The mobile app also allows users to search across the incidents and database resources and the best practices can be viewed offline.

FIGURE 1. Hydrogen Safety Panel Logo

During the development of the Hydrogen Tools app, the question was raised: "Do we have the right tools to support this next phase toward hydrogen and fuel cell commercialization?" PNNL conducted a planning session in Los Angeles, CA on April 1, 2014 to consider what electronic safety tools would benefit the next phase of hydrogen and fuel cell commercialization. A diverse, 20-person team led by an experienced facilitator considered the question as it applied to the eight most relevant user groups. The planning session revealed areas where users of safety information could benefit from a new approach to safety knowledge resources. Three example high-impact tools include:

- A hydrogen safety portal – a nexus for safety information and professional networking that integrates electronic safety resources into one location. A portal could integrate existing resources to facilitate accessibility (and display) from a single, *trustworthy* source, increasing their visibility and value.
- A codes and standards guide – a tool to guide the user through questions relating to application, topics and subtopics to help them identify the applicable requirements in a timely manner.
- Peer networking tools – tools to allow users to to discuss relevant hydrogen safety and code application topics with counterparts.

Implementing these tools will be a transformative step toward disseminating safety information and enabling fuel cell commercialization. A summary document will be made available near the end of FY 2014.

In June 2014, "H2incidents.org" was renamed "Hydrogen Lessons Learned (H2LL)," and relocated to a new Internet address, "h2tools.org/lessons/." These changes facilitate broader acceptance of the resource and make it part of the hydrogen safety portal.

CONCLUSIONS AND FUTURE DIRECTIONS

The HSP will continue to focus on how safety knowledge, best practices and lessons learned can be brought to bear on the safe conduct of project work and the deployment of hydrogen technologies and systems in applications of interest and priority in the DOE FCT Office.

The Panel can also be used more broadly as an asset for safe commercialization by reaching out to new stakeholders and users involved in early deployment activities.

The project will undertake a number of initiatives over the next year, including:

- Support project activities with the focus on early engagement, including kickoff meetings, safety plan reviews, site visits and other relevant interactions with project teams.
- Expand the Panel's visibility through a web page and integration into key social media tools.
- Work with DOE to strengthen contract language to support HSP early involvement in projects and a commitment to NFPA 2 implementation; and submit proposed changes to DOE project safety planning through an update to the document, "Safety Planning Guidance for Hydrogen and Fuel Cell Projects."
- Identify opportunities to support H2USA (H2USA is a public-private partnership to promote the commercial introduction and widespread adoption of fueled fuel cell electric vehicles across the United States with a mission to address hurdles to establishing hydrogen fueling infrastructure).
- Submit a draft hydrogen certification guide to DOE.
- Achieve an appropriate mix of safety expertise and perspective to perform safety reviews and address relevant issues. PNNL will continue to evaluate the Panel membership to maintain its leadership role in hydrogen safety.
- Seek opportunities to share safety knowledge with new audiences to facilitate the safe deployment of hydrogen and fuel cell technologies.

Hydrogen safety knowledge tools help remove barriers to the deployment and commercialization of hydrogen and fuel cell technologies. While feedback on the existing resources has been positive, a concerted effort beyond just general maintenance is necessary to remain relevant and impactful to the community being served. Working toward that goal, in FY 2014 the project will:

- Develop a "Hydrogen Tools" portal that combines existing hydrogen safety resources into one centralized and integrated website.
- Support the development of new tools identified during the April 2014 planning session.

FY 2014 PUBLICATIONS

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14. Barilo, N.F. to Kleen, G., "Hydrogen Safety Panel Review of the Safety Plan for High Performance, Durable, Low Cost Membrane Electrode Assemblies for Transportation Applications," March 25, 2014.

15. Barilo, N.F. to Peterson, D., "Hydrogen Safety Panel Review of the Safety Plan for the 3M Project 'New Fuel Cell Membranes with Improved Durability and Performance' (EE0006362)," May 8 2014.

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17. Barilo, N.F. to Choe, B. "Hydrogen Safety Panel Review of the Fuel Cell Hybrid Electric Drayage Truck Safety Plan," June 23, 2014.

18. Barilo, N., "The H Factor," NFPA Journal®, May/June 2014, available online at http://www.nxtbook.com/nxtbooks/nfpa/journal_20140506/index.php#/80.

19. Barilo, N.F., "Design to Operations: Integrating Safety into Hydrogen and Fuel Cell Projects," 2014 NFPA Conference & Expo, Las Vegas, NV, June 10, 2014, available online at http://www.nfpa.org/~/media/2B0101A61A9346C595C7BB77A3A74A06.pdf.

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